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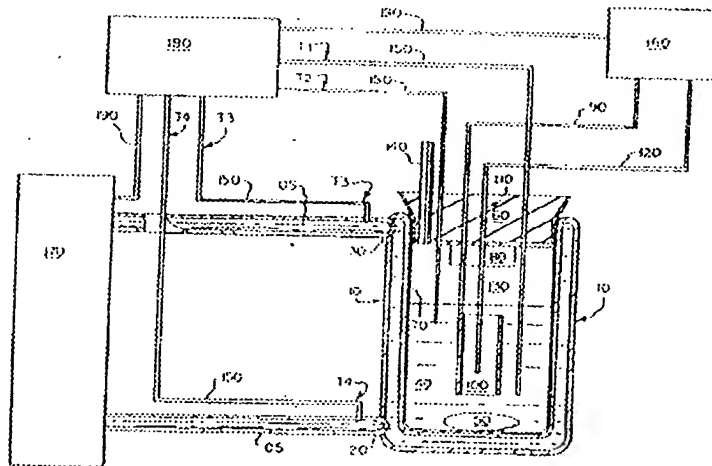
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COPY

(54) Title: METHOD AND APPARATUS FOR ALKALI-HYDROGEN FUSION POWER GENERATION



## (57) Abstract

An electrolyte (40) consisting of an aqueous solution of a soluble compound of thallium or any of the alkali type elements (hydrogen, deuterium, tritium, lithium, sodium, potassium, rubidium, cesium, francium), in contact with an angular porous cathode (100) of a sinter-bonded mixture of nickel powder and nickel fibers for catalysis of nuclear fusion reactions between hydrogen nuclei from ordinary water and nuclei of the alkali type elements in the soluble compound whereby thermal power generation by the Fleischmann-Pons cold fusion process is improved. In a preferred embodiment the electrolyte consists of a solution of sodium carbonate in ordinary water and the cold fusion *TRINE* process converts the sodium into magnesium by reducing the total number of hydrogen atoms in the water and producing a corresponding quantity of molecular oxygen.

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METHOD & APPARATUS FOR  
ALKALI-HYDROGEN FUSION POWER GENERATION

Technical Field

This invention relates to the field of excess  
5 enthalpy production by so-called Cold Fusion as disclosed  
by electrochemistry Professors Martin Fleischmann, F.R.S.  
and Stanley Pons on March 23, 1989; it particularly  
concerns an empirical improvement of their process  
published by Dr. Randell L. Mills and S. P. Kneizys in  
10 *Fusion Technology*, Vol. 20 (August 1991), No. 1, pp.  
65-81, wherein ordinary water is used instead of heavy  
water. However we have found it necessary to reject the  
novel chemistry upon which their own explanation of their  
results has been based, because their theory makes  
15 predictions which we have falsified by careful  
experiment, a preliminary account of which is to be  
published in the paper "A Light Water Excess Heat  
Reaction Suggests That 'Cold Fusion' Is 'Alkali-Hydrogen  
Fusion'", by Robert T. Bush, to appear in *Fusion*  
20 *Technology*, presently scheduled for May, 1992 [Abstract  
already published in *Fusion Facts*, December, 1991],  
hereinafter referred to as reference B92, which is a  
continuation of the already published work on the TRM  
(Transmission Resonance Model) and TRINT (Transmission  
25 Resonance Induced Nuclear Transmutations) of Bush which  
appeared in *Fusion Technology*, Volume 19 (March 1991),  
pp. 313-356, hereinafter referred to as reference B91.

Background Art

The world was rightfully startled on March 23, 1989  
30 when two electrochemistry professors at the University of  
Utah announced the discovery of (essentially aneutronic)  
electrochemically induced excess enthalpy in such large  
amounts per cubic centimeter of cathode (and/or  
electrolyte) that it seems to have no possible  
35 conventional chemical explanation and was therefore  
assumed by them to involve nuclear fusion reactions in a  
so-called "cold fusion" process.

This explanation of their carefully-done  
calorimetric experiments became controversial because,

according to the accepted theory of fusion reactions as used e.g. in conventional "hot fusion", or "controlled thermonuclear fusion" reactor research, the deuterium nuclei in the heavy water used by Fleischmann & Pons would have to have kinetic energies of the order of keV (rather than the eV levels of chemical potential inside of their deuterium-saturated palladium cathodes). It may be possible, however, to overcome this objection entirely within the realm of conventionally accepted microphysical principles, based upon consideration of the periodicity of the lattice structure in the metallic host cathode.

For example, UCLA Prof. Emeritus Julian Schwinger, a Nobel Laureate in theoretical physics, has published a series of papers on *NEAL* (Nuclear Energy in an Atomic Lattice) in which he develops a quantum-mechanical model of deuterons in a host lattice in which the totality of positive and negative charges in the lattice (from both bound positive nuclei and bound and free lattice electrons) interact in such a manner that the net forces on a bound deuterium pair can be approximated as that of a quantized harmonic oscillator. (In other words the potential tends to a constant function of  $r$  (as  $r$  tends to zero) rather than  $1/r$ , if  $r$  denotes the distance between a pair of bound deuterons.) At the Second International Conference on Cold Fusion, Lake Como, Italy, July 1-3, 1991, former BYU Physics professor Robert W. Bass presented a paper on his *QRT* (Quantum Resonance Triggering) principle, in which, building upon Schwinger's *NEAL* theory, and attempting to develop a quantitative interface between Schwinger's *NEAL* and Bush's *TRM*, he computed that raising the energy level of one of the quantized Schwinger oscillators composed of a pair of bound deuterons by as little as 5.1 eV would bring the deuterons sufficiently close to one another to assure a fusion reaction. In the *QRT* model, the required energy comes from a collision with another deuteron which

is moving freely inside the periodic lattice according to the TRM (Transmission Resonance Model) of Robert T. Bush, published in B91 and improved in B92. Bush's TRM model is based upon the quantum-mechanical TRC (Transmission Resonance Concept) suggested in this context by Dr. Leaf Turner of the Los Alamos National Laboratory in a Letter to the Editor, *Physics Today*, September 1989, Vol. 42, page 140, after having been presented at the Workshop on Cold Fusion Phenomena, Santa Fe, NM, May 23-25, 1989. (It was shown by Bass that the TRC can be derived from the pre-quantum mechanical Duane Rule of 1924, which "Duane ansatz," Bush has shown [*Lettere al Nuovo Cimento*, July 1982, Vol. 34, p. 363 and February 1983, vol. 36, p. 241] can be derived from Heisenberg's Uncertainty Principle.) According to Bush's TRM, the electrical double-layer at the lattice-electrolyte interface will contain a distribution of deuterons of different kinetic energies, some of which will have the [Duane Rule] linear momentum of e.g. 5.1 eV, which is sufficient to allow free translation within the periodic lattice. And according to Bass's QRT such a deuteron can exchange linear momentum with a Schwinger oscillator, bringing it to its 41st quantum level above the zero point, in which the amplitude of the oscillations is so large that the deuterons almost touch, and the short-range nuclear force ensures fusion.

Assuming that the periodicity of the host lattice can provide a plausible mechanism for nuclear fusion, another difficulty remains. According to the accepted probability cross-sections, two fusing deuterons will produce either a proton and a triton or a neutron and a helium-3 nucleus with approximately equal probability; the possibility of the fusion producing a helium-4 nucleus is supposed to be many orders of magnitude smaller in comparison. But in their first publication Fleischmann, Pons & Hawking pointed out that the upper limits on the possible production of either tritium or

neutrons in their exenthalpic experiments were so small in comparison to the heat energy manifested by a rise in cathode temperature that the conventional fusion "branching ratio" can not possibly be applicable under the conditions of their electrolytic cells.

Meanwhile, this "branching ratio" mystery was increased by independent work from BYU Physics Professor Steven E. Jones, who since the mid-1980's had been publishing and lecturing on his concept of "piezonuclear fusion", in which he attempted to prove theoretically (and, after 1986 to demonstrate experimentally) that deuterons loaded into a host lattice can be brought to conditions of sufficient "equivalent pressure" as to produce, at a very small rate, conventional fusion reactions of the type studied in hot fusion experiments and also in a kind of cold fusion known as "muonic fusion" in which the electrons in a deuterium gas are replaced by muons, reducing the size of the deuterium atoms and bringing the nuclei sufficiently close for quantum tunneling to produce some fusions. However, muonic fusion seems marginal as to utility, and so Jones conceived of and turned to investigate "piezonuclear" fusion; reportedly, this concept had already been published in the Soviet Union under the name of "picnofusion", wherein the prefix picno is supposedly the "correct" geological term for high pressures.

High energy physicists have accepted the work of Jones more readily than that of electrochemists Fleischmann & Pons, in part because during the past two years a vast number of papers on "anomalous nuclear phenomena in deuterated metallic lattices" have been published, with so many different investigators finding diagnostic indicia of previously unobserved nuclear reactions that the possibility that this huge body of reports consists one hundred percent of errors and mistakes seems vanishingly small. But Jones and many of the nuclear physicists who do not dismiss his work as

mistaken believe that there is no way that the excess energy of a newly created alpha particle can be transferred to the host lattice in what chemists Walling & Simons have called a RR (Radiationless Reaction), and therefore remain skeptical of the objective validity of the excess enthalpy claims, based upon macroscopic calorimetry, of Fleischmann & Pons and the various electrochemists (notably Prof. Huggins of Stanford, and Dr. M. McKubre of SRI, as well as Bockris & Appleby of Texas A&M) who have confirmed and extended their work.

An example of the extreme skepticism of some electrochemists and some theoretical physicists toward the Fleischmann-Pons type of cold fusion was published in the *Los Angeles Times* on March 23, 1990 by Caltech electrochemist Nathan S. Lewis and Caltech theoretical physicist Steven E. Koonin: "When Cold Fusion Got Hot it Rapidly Fizzled. ... The premise of unlimited energy set off a frenzy of activity. But publicity alone couldn't make claims of a breakthrough true. ... Although cold fusion excited our imagination, in the end it was just another corrected mistake." Equally negative is the book of British nuclear physicist Frank Close, *Too Hot to Handle*, published in the USA in 1991 by Princeton University Press.

More balanced and objective surveys are to be found in the books *Cold Fusion: The Making of a Scientific Controversy* (Contemporary Books, 1989 & 1990), by Canadian theoretical physicist F. David Peat, and *Fire From Ice: Searching for the Truth Behind the Cold Fusion Furor* (Wiley, 1991), by engineer Eugene F. Mallove. Other sources of information favorable to the reality of cold fusion include the monthly newsletter *Fusion Facts*, the semi-popular magazine *Twenty First Century Science & Technology*, and the section on cold fusion in the archive journal *Fusion Technology*, published by the American Nuclear Society.

According to a review of 242 references in the June 1991 issue of *Fusion Facts*, cold fusion "successes" have been reported from 23 countries. Also, in the April 25 issue of *Current Science* (published in India), a remarkably thorough and objective survey of 174 published references entitled "Nuclear Fusion in an Atomic Lattice: An Update On the International Status of Cold Fusion Research" was presented by Dr. M. Srinivasan of the Neutron Physics Division of the Bhaba Atomic Research Centre in Bombay. The present inventors believe that no scientifically educated and unbiased reader of Srinivasan's report can possibly doubt the reality of either Jones' anomalous nuclear effects in deuterated lattices or the more revolutionary Fleischmann-Pons excess enthalpy cold fusion phenomenon.

Since experiment rather than prejudiced theory must have the final word, it has to be accepted that somehow aneutronic fusion reactions can occur in a deuterated lattice. One possible explanation can be found in the NEAL theory of Schwinger, in which quantum electrodynamic selection rules prohibit the excited alpha particle (resulting from a deuteron-deuteron fusion) from photon emission, but allow it to fall into its ground state by emission of a large number of phonons into the lattice. If correct, this would validate the Walling-Simons RR theory, and dispel the anomalous branching-ratio problem.

Accordingly the present inventors find no reason to regard the reality of cold fusion as "unacceptable" to the present understanding of the laws of microphysics. In fact, one of them (R.T. Bush) has used the Bush TRM theory to predict (B91) a remarkably nonlinear fine structure (exhibiting local maxima and minima) to the excess power in a Fleischmann-Pons cell as a function of either current density, cell temperature, or hydrogen overvoltage (when the other two are held constant); furthermore, in their own calorimetric experiments (e.g. *Fusion Technology*, Vol. 20 [September 1991], pp. 239-245)



the present inventors have verified all predictions of the Bush TRM model and have not encountered any inconsistencies with its predictions.

As astonishing as the original Fleischmann-Pons disclosure has been that of the Mills-Kneizys paper referenced above. Fleischmann and Pons have not claimed excess enthalpy from ordinary water cells in their archive publications, although certain attendees of their public lectures claim certainty that they have "admitted" publicly that they did observe a small amount of excess enthalpy in light-water experiments, but downplayed it as an embarrassment to their credibility of their heavy-water discoveries; at any rate, in their international patent application, they do claim excess enthalpy from electrochemically-induced cold fusion reactions involving a metallic cathode and an ordinary water electrolyte containing lithium hydroxide. Most researchers regarded this possibility (given the difficulties of replication of the heavy water experiments) as marginally small and not to be taken seriously as a possible source of energy in commercially useful quantities. However, to the astonishment of the few hundred scientists who have continued to research the heavy-water, palladium cathode excess enthalpy process, Mills & Kneizys claim easy replicability of production of large amounts of macroscopic heat energy from a periodically electrically-pulsed cell containing potassium carbonate dissolved in ordinary water and in contact with a solid nickel cathode. Moreover the present inventors have not only essentially duplicated that claim of Mills & Kneizys (though with a porous nickel cathode) but have been told [private communication] by an internationally reputable calorimetrist, Dr. Noninsky, that he has not only confirmed the reality of the excess enthalpy in the Mills-Kneizys type of cells, but has induced a Dr. McBrien of the Brookhaven National Laboratory to also

independently verify the reality of this truly revolutionary discovery.

For convenience, we will henceforth refer to the Fleischmann & Pons type of cold fusion, predominantly concerned with heavy water, as the FP phenomenon, and the Mills-Kneizys type of cold fusion, disclosed principally in terms of ordinary water, as the MK phenomenon.

Although, as previously explained, it seems possible to understand the FP phenomenon in terms of the accepted laws of physics, the majority of "establishment" physicists believe that the FP phenomenon is so implausible theoretically that they prefer to regard FP experiments as illusory and mistaken rather than to seek to integrate the phenomenon into the accepted body of scientific "knowledge". Obviously, if the FP deuteron-fusion claim is regarded as implausible, and stated to be "unbelievable" unless performed in parallel with similar experiments using ordinary water instead of heavy water and expected to be control "blanks", then the MK phenomenon will be regarded as so implausible as not to be worthy of further consideration.

Although the present inventors believe that Mills and Kneizys have given the world a scientific/technological treasure of inestimable value, we believe that it has the value of an empirical discovery rather than a scientific advance. This is because we cannot accept the Mills-Farrell novel chemistry (*The Grand Unified Theory*, Science Press, Ephrata, PA) which is used by Mills & Kneizys to "explain" the MK phenomenon. Briefly, they reject Heisenberg and Schrodinger's work, and develop their own atomic theory, which permits atoms to have energy levels that would, in conventional quantum mechanics, correspond to fractional quantum numbers. For example, in the Bohr model of the hydrogen atom, the electron's orbit is such that  $n = 1$  de Broglie wavelengths equal the circumference at the corresponding radius, and there is no lower-energy

state with a smaller radius; but if the quantum number  $n = 1/2$  were allowed, then the size of the hydrogen atom could be "shrunk". In the novel Mills-Farrell chemistry, potassium carbonate supplies an "energy hole" which  
5 "resonates" with an entering hydrogen atom in such a way as to "shrink" it. (Such a shrunken hydrogen atom would remain shrunken almost forever, because the chances are vanishingly small that it would ever encounter a gamma-ray photon of exactly the right resonant energy to  
10 raise it back to the old  $n = 1$  energy level and larger size.)

While we agree with Dr. Mills that we "do not accept incumbency as a validation of scientific argument", we find that numerous predictions of his novel atomic  
15 physics are in contradiction to many well-verified experimental measurements and therefore his theory must be rejected (at least, in its present form). Unfortunately, misunderstanding of the MK phenomenon limits the ability of its discoverers to teach others to  
20 make and use their discovery, or to extend it to other elements; normally they would be entitled to intellectual property rights to their staggeringly monumental improvement of the FP phenomenon, but, sad to say, their conviction of the correctness of their novel chemistry is  
25 so great that all of the claims in their international patent application (WO 90/13126, filed April 13, 1990) involve "resonance shrinkage energy levels" and/or "energy holes" which according to conventional physics do not exist, and which the present authors have satisfied  
30 themselves experimentally are false concepts because they make predictions which we ourselves have falsified in experiments disclosed herein.

That is, if the novel MF chemistry makes predictions regarding the MK phenomenon which are contradicted by  
35 experiment, which the present inventors explicitly claim to be the case, then the novel MF chemistry cannot be relied upon in attempting to make and use "without undue

experimentation", and accordingly the intellectual property rights claimed in the MK patent application are null and void because they prescribe a methodology which has internal contradictions and which is therefore  
5 useless. In other words, their paper has placed their intellectual property in the public domain because their patent claims were formulated in terms of their novel but demonstrably incorrect chemistry, rather than empirically/operationally. We regret the necessity of  
10 this harsh conclusion, but it has been forced upon us by facts and experiments which will now be disclosed.

One of the present inventors (Robert T. Bush) was, at one time, a student of the history of science, and he is well acquainted with the fact that yesterday's heresy  
15 may be tomorrow's orthodoxy. Accordingly he read the MK paper with an open mind. In collaboration, the present inventors found no difficulty in confirming the existence of the MK phenomenon as regards potassium carbonate in an ordinary water electrolytic cell equipped with a nickel  
20 cathode. But according to the novel MF chemistry, no excess enthalpy should be obtained if one repeats the MK experiment, substituting sodium carbonate for potassium carbonate. In fact, MK established their technology by using a sodium cell as a "blank" for comparison with an  
25 "operable" potassium cell.

When we repeated the MK experiment, improving upon the design of the MK electrolytic cell by replacing the smooth, solid nickel cathode which they used by a hollow, annular, porous cathode made of sinter-bonded nickel  
30 powder and nickel fibers, then we not only got more reliable results with potassium, but, contrary to the novel MF chemistry, we got about twice as much power when we replaced the potassium by sodium!

In short, the very foundation of the MK technology  
35 is to use sodium carbonate as an inoperable blank in comparison to the operable use of potassium carbonate. But when we constructed a cell of enhanced efficiency,

11

the "blank" using sodium turned out to be twice as useful as the MK-recommended use of potassium.

5 In fact, using conventional nuclear physics, and the type of TRM/NEAL/ORT theory, used to "explain" the FP phenomenon, to suggest the plausibility of inducing low-temperature nuclear transmutations other than those envisaged by FP, one of the present inventors (R.T. Bush) had already started to write a paper, B92, explaining the MK phenomenon on the basis of conventional physics  
10 as the result of fusion of a proton (from the ordinary water) with a potassium nucleus to give a calcium nucleus plus heat. When we made the surprising discovery that sodium, far from being the "blank" claimed by MK, was actually twice as reactive as potassium, one of us (Bush) returned to the theory of B92 and soon worked out a  
15 prediction that a sodium cell should produce 1.8 times as much heat as a potassium cell [equation (78c) of B92], which compares so favorably with our experimental measurement of  $1.90 \pm 0.33$  [equation (72) of B92] that we  
20 regard this originally unexpected result as both definitive refutation of the MF novel chemistry and the MK predictions based thereon and as strong confirmation of the validity of the 'new TRM model', of B92.

25 In a private communication we have learned from William Good, a chemist collaborating with Dr. Mills in developing the MK technology, that although he had run a very high power (hundreds of watts) MK cell for many months it had never occurred to him to look for extra calcium being created by the nuclear transmutation of  
30 potassium in the presence of ordinary water, and that he was certain that there could have been no calcium created, because the amount of heat produced was so large that the amount of calcium created would have been macroscopically observable in the form of precipitation  
35 on the nickel cathode. To the contrary, the TRINT theory of B91 & B92 shows that creation of a relatively small amount of calcium will produce a relatively enormous

amount of heat, and the calcium "ash" will be so microscopically minute that it must be looked for deliberately using sophisticated analytic techniques.

As reported in B92, we did look for calcium "ash" under the *TRINT* hypothesis that our cell was nuclearly transmuting a "fuel" composed of protons (from the ordinary water) and potassium nuclei (from the potassium carbonate dissolved in the ordinary water). In cell 44 we measured the creation of 14 micrograms of excess calcium, which our theory predicts would correspond to an average excess power of 0.25 W during a 13-day run in which the average excess power actually measured was  $(0.31 \pm 0.08)$  W. For cell 45 the correlation between excess power and excess calcium was also fairly good: we measured 31.9 micrograms of excess calcium, which according to conventional nuclear physics should correspond to an average excess power of 0.49 W over a 15-day run, whereas we actually measured  $(0.58 \pm 0.15)$  W.

As explained in much greater scientific depth and technical detail in B92, considerations of established nuclear physics regarding the relative stability of certain configurations of protons and neutrons as opposed to other nucleonic configurations (involving e.g. the so-called [bold-face] "magic numbers" [and other numbers of protons and neutrons that produce ultrastable nuclear configurations] 2, 6, 8, 14, 16, 20, 28, 32, 38, 40, 50, 58, 64, 76, 80, 82, 92, 100, 120, 124, 126, ... listed in texts on the shell model of the nucleus) have led one of us (R.T. Bush) to extrapolate the preceding experimental results to the first seemingly complete theory of cold fusion as in reality 'alkali-hydrogen' fusion, a concept which goes beyond the basic FP phenomenon into the realm of Bush's concept of *TRINT* (Transmission Resonance Induced Nuclear Transmutations).

For example, the 'new *TRM* model' of B92 predicts that we can replace potassium carbonate by rubidium

carbonate and then, in addition to the measurement of excess heat, we can measure the creation of excess strontium. We have actually done this. In cell 49, we measured the creation of  $(3.2 \pm 0.4)$  micrograms of strontium, which according to conventional nuclear physics should have produced  $(37 \pm 17)$  kJ of excess heat, while we actually measured  $(37 \pm 6)$  kJ of excess heat.

Finally, at the urging of Dr. Eugene Mallove, we performed a somewhat complicated dilution experiment (the details of which will be found in B92) in which the variation in excess heat was measured in a working light water cell while heavy water was added. Briefly this confirmed our theory that excess heat in light water experiments cannot be explained as the result of contamination by heavy water, and also indicated that in the type of cold fusion method and apparatus as disclosed herein the cross sections for fusion of a deuteron and a proton to make helium-3 and the fusion of two deuterons to make helium-4 are approximately equal.

Consequently we regard the validity of the present *TRINIT* theory of cold fusion as well established, and with confidence we can make extrapolations which we have not yet reduced to actual practice (such as the combination of a proton from ordinary water with a cesium nucleus to make a barium nucleus, or similar use of thallium to make lead); indeed, we have concluded that the group of elements comprising thallium plus the alkali elements is unnecessarily restricted, and the group should be generalized to include any nuclide which has the property that when it gains one proton (from ordinary water) or one deuteron (from heavy water) there is a resultant nuclear mass defect.

In summary, although the original FP phenomenon is of monumental significance, and the empirical improvement of the MK phenomenon is of even greater potential import, the FP phenomenon suffers from the limitation to

relatively expensive materials such as heavy water and palladium, while the MK phenomenon was incorrectly understood and therefore its least expensive embodiment, namely the transmutation of [dirt cheap!] sodium to magnesium using ordinary water, was falsely predicted to be impossible and indeed sodium was used in the MK experiments as an ideal blank, whereas in the present invention sodium produced twice as much heat as can be obtained from the MK phenomenon's prescribed potassium.

10 Disclosure of invention

Accordingly it is an object and an advantage of the present invention to improve the FP phenomenon by elimination of the need to use relatively expensive heavy water and its replacement by ordinary (light) water.

15 It is also an object and an advantage of the present invention to improve the FP phenomenon by elimination of the need to use relatively expensive metals, such as palladium, for the cathode.

It is also an object and an advantage of the present invention to improve the FP cold fusion process by generalizing it to an entire field of *TRINT* (Transmission Resonance Induced Nuclear Transmutation), namely the field which we call "Alkali-Hydrogen Fusion" in which one of the reactants is any isotope of hydrogen and the other reactant is either thallium or any isotope of any of the alkali-type elements (where we classify hydrogen itself as among the alkali-type elements).

It is also an object and an advantage of the present invention to enable the public-domain MK phenomenon improvement of the FP phenomenon to be applied via scientific chemical-process engineering in accordance with accepted scientific principles and procedures rather than empirically by trial-and-error or excessive experimentation based upon a novel theory of chemistry which contradicts many known facts and which even in the limited field of cold fusion makes predictions that are



demonstrably false (such as that sodium is a 'blank' rather than one of the best possible reactants).

It is also an object and advantage of the present invention to improve the practical utility of the FP process as to reliability, simplicity, and cost-effectiveness by making possible cold fusion heat and power generation sources based upon cheaper and more common ingredients and less complexity of preparation.

#### Description of drawings

Figure 1 depicts a Proof of Principle embodiment of the present invention in a desk-top experiment based upon forced flow calorimetry wherein the coolant is the bath.

Figure 2 depicts the electronic control and data recording system used in connection with the embodiment of Figure 1.

#### Reference Numerals in Drawings

- 05 coolant fluid
- 10 double-walled flowing coolant 05 container of electrolyte 40
- 20 20 coolant inlet
- 30 30 coolant outlet
- 40 40 electrolyte
- 50 50 teflon coated magnetic stirrer
- 60 60 teflon coated stopper
- 25 70 70 teflon coating
- 80 80 recombiner catalyst
- 90 90 current conductor from cathode
- 100 100 annular porous metallic cathode
- 110 110 rodlike solid metallic anode
- 30 120 120 current conductor to anode
- 130 130 evolved gases ( $O_2$  and  $HD$ ,  $H_2$ ,  $D_2$ ,  $HT$ ,  $DT$ , &  $T_2$ )
- 140 140 pressure regulator and isolator
- 150 150 thermocouples ( $T_1$ ,  $T_2$ ,  $T_3$ ,  $T_4$ )
- 160 160 current regulation system
- 35 170 170 coolant flow regulation system
- 180 180 electronic data monitoring and control system
- 190 190 electronic signal transmission lines

- 200 electrolytic cell (05 - 80, 100 - 110, 130 -  
150, 170)  
210 32-channel multiplexer  
220 8-port A to D converter  
5 230 digital computer or controller  
240 IEEE bus  
250 dual display multimeter and input power  
(current, voltage) regulation system

#### Mode for Carrying out the Invention

10 Except for certain special choices of materials,  
this is a standard cold fusion cell of the type  
introduced by Fleischmann and Pons, except improved in  
the manner of Huggins by employment of a catalytic  
recombiner to make possible closed-cell calorimetry.

15 As seen in Figures 1 & 2, the coolant fluid 05 fills  
a double-walled container 10 provided with an inlet 20  
and an outlet 30. The container 10 contains an  
electrolyte 40 which can be stirred by teflon coated  
magnetic stirrer 50. The container is closed by a teflon  
20 coated stopper 60 and the interior surface of the  
container is coated with a teflon coating 70. The  
recombiner catalyst 80 causes oxygen and hydrogen gases  
evolved by the electrolysis process to recombine as  
liquid water and then (by gravity) to return to the  
25 electrolyte 40. Electrical current conductor 90 conducts  
current away from annular porous metallic cathode 100.  
Rodlike solid metallic anode 110 fits in the interior of  
the cathode 100. Current conductor 120 conducts current  
into the anode 110. Evolved gases 130 rise above  
30 electrolyte 40 and fill the space between electrolyte 40  
and stopper 60. Pressure regulator and isolator 140  
opens into the space filled by evolved gases 130.  
Thermocouples 150 monitor various temperatures; T1 near  
the bottom of the electrolyte 40, T2 near the top of  
35 electrolyte 40, T4 at coolant inlet 20 and T3 at coolant  
outlet 30. The current regulation system 160 could be a

separate system but in the presently preferred embodiment is one function of the computer 230. The coolant flow regulation system 170 is a mechanical subsystem of the combined cell and cooling system 200. System 170 can function autonomously if it has its own control computer, or it can be operated by control computer 180 through a signal line 190 if it is not autonomous. The electronic data monitoring and control system 180 could be a separate system but in the presently preferred embodiment is one function of the computer 230. Electronic signal transmission lines 190 connect the control system 180 with the current regulation system 160 and the flow regulation system 170. Electrolytic cell 200 comprises the components 05-80, 100-110, 130-140, and 170. The 32-channel multiplexer 210 connects the thermocouples with the controller 230 via an 8-port A to D converter 220. The controller 230 is a digital computer which functions both as a current regulation system 160 and as a data monitoring and control system 180. An IEEE bus 240 connects the controller 230 with the dual display multimeter 250 which acts as the input power regulation system by controlling both the voltage and the current to the conductor 120 to the anode and completing the closed circuit with the conductor 90 from the cathode.

The presently preferred embodiment depicted in Figures 1 and 2 is a Proof of Principle embodiment. This is not a planned or hypothetical embodiment but a depiction of an embodiment which has been reduced to actual practice, which produced the results mentioned above and which is reported in greater detail in the peer-reviewed archive journal publication B92.

For large-scale power production the presently disclosed process can be enhanced both by known techniques of power production systems and by the techniques disclosed by us in our co-pending application "Method and Apparatus for Energy Production Using Cold Nuclear Fusion" (Application Number 07/352,853, filed May

15, 1989) and its continuation-in-part "Method and Apparatus for Energy Production Using Cold Nuclear Fusion with a Lithium Deuterioxide Electrolyte" (Application Number 07/446,615, filed December 6, 1989). The  
5 elementary closed-loop control system presently disclosed can be enhanced both by known techniques of automatic control system technology and the techniques disclosed by us and co-inventors Robert W. Bass, Jay A. Blauer, Alfred Fermelia, Stephen J. Pike, and Herbert E. Ransford III in  
10 our co-pending application "Optimal CLM Computrol of Cold Fusion Power" (Application Number 07/678,537, filed March 31, 1991). In particular the magnetostrictive and electrostrictive properties of nickel can be used to adjust the micro-structure of the lattice as disclosed in  
15 the just-cited CLM (Closed Loop Methodology) Computrol patent application, in accordance with the TRM and TRINT models of references B91 & B92 and the QRT principles disclosed in the pending application of Robert W. Bass entitled "Quantum Resonance Heating Method" (Application  
20 Number 07/722,687, filed June 28, 1991).

Referring again to Figures 1 to 2, the cold fusion cell and cooling system 200 is operated by means of a closed-loop control system 180 which in the presently preferred embodiment is one function of the digital  
25 computer or controller 230.

In operation control system 180 computes actuation commands sent via signal transmission lines 190 to current regulation system 160 and to coolant flow regulation system 170.

30 Coolant flow regulation system 170 regulates the rate of flow of coolant 05 out of outlet 30 and into inlet 20. By monitoring the temperature of the electrolyte 40 through bottom T1 and top T2 thermocouples 150 and comparing the mean of T1 and T2 with the  
35 difference between outlet T3 and inlet T4 thermocouples 150 the rate of heat production  $P_h$  inside container 10 can be measured continuously. Likewise the input power  $P_i$  to

the container can be computed by computer 230 by simple multiplication of the commanded input voltage  $V$  and input power amperage  $i$  to give input power  $P_i = V \cdot i$ . Then the excess power  $P_e = P_h - P_i$ . This power is available for  
5 use after extraction from the coolant 05 by standard power conversion techniques.

In steady-state operation current  $i$  at voltage  $V$  enters anode 110 via current conductor 120, passes through electrolyte 40 and cathode 100 before returning  
10 through current conductor 120 to a power supply (not shown).

The electrolysis of electrolyte 40 separates this aqueous solution into gaseous molecular oxygen at anode 110 and (isotopic) molecular hydrogen at cathode 100,  
15 which gases bubble up into space 130 between electrolyte 40 and stopper 60. Recombiner catalyst 80 causes the (isotopic) hydrogen and oxygen to combine into (isotopic) water, which by gravity eventually returns to the electrolyte 40.

20 The cold fusion reaction takes place on the surface of, or inside the metallic lattice of the cathode 100. In one preferred embodiment, the electrolyte 40 consists of ordinary water within which there is dissolved sodium carbonate. As hydrogen nuclei from the water combine  
25 with sodium nuclei from the dissolved carbonate to produce magnesium, some of the water is converted to oxygen molecules for which there are insufficient hydrogen atoms to recombine into water, therefore the cell's excess oxygen and excess magnesium must eventually  
30 be removed before the process can be refueled by the introduction of new amounts of water and sodium. Thus the TRINT nuclear "fuels" consist of water and sodium and the "ash" consists of magnesium and oxygen.

#### Industrial Applicability

35 As recently as three years ago it was not believed possible to effect nuclear transmutations except through expensive high-energy machines such as particle

accelerators, or fission or thermonuclear fusion reactors.

5        *TRINT* (Transmission Resonance Induced Nuclear Transmutation), disclosed herein, is a major technical breakthrough which may affect civilization even more than the known technology of Nuclear Fission Chain Reactions or the emerging technology of Controlled Thermonuclear Fusion Reactions. The existence of *TRINT* was unsuspected until the discovery of the FP phenomenon. Even if *TRINT* 10 had remained confined to use of heavy water only, it had the potential of providing mankind with limitless, cheap, non-polluting energy. The empirical discovery of the MK phenomenon opened the door to enormous simplification by use of ordinary water instead of heavy water. Sad to 15 say, Mills and Kneizys failed to protect their intellectual property adequately by stating all of their patent claims in terms of a novel chemistry which, unlike conventional chemistry, makes predictions that are demonstrably false. Thus, although they have made a vast 20 contribution to technology, they regrettably lost their intellectual property rights by misguided commitment to a novel but false theoretical framework, which also made it impossible for them to discover the most cost-effective modification of the MK process, namely the use of sodium as a fuel with magnesium as the ash (which they 25 mistakenly stated would be a "blank" against which to measure the success of MK processes). The present invention is an improvement of the (public domain) MK process in directions which their novel but mistaken 30 theory could never have foreseen. Moreover, the theory upon which the present invention rests has been demonstrated to be correct by actual reduction to practice of four separate embodiments of the present invention, which employ, respectively, potassium, sodium, 35 rubidium and deuterium as the primary "fuel" to be nuclearly transmuted with either light or heavy water to produce an "ash", respectively, of calcium, magnesium,

strontium, and helium. The present inventors have made actual measurements of the "ash" in actual working embodiments and proved that, within the limits of the accuracy of their instrumentation, the excess heat  
5 corresponds precisely to that which would have been predicted from conventional nuclear physics according to the known equivalence between mass and energy derived in the theory of special relativity. Thus the present invention, although admittedly not a pioneer invention  
10 (and the inventors acknowledge that in standing upon the shoulders of Fleischmann & Pons and Mills & Kneizys they are standing upon the shoulders of giants) seems to represent a certain completion and culmination of the field of cold fusion in that unsuspected and unenvisioned  
15 versions of cold fusion (such as the transmutation of rubidium to strontium in a simple room-temperature table-top apparatus) have been predicted by the novel TRINT principles disclosed herein and subsequently demonstrated by actual reduction to practice to have  
20 operated quantitatively precisely as planned, thereby removing cold fusion from the category of a partially unpredictable technology and placing it firmly in the category of predictable technologies.

Although the description above contains many  
25 specificities, these should not be construed as limiting the scope of the present invention but as merely providing illustrations of some of the presently preferred embodiments of this invention. For example, if heavy water instead of light water and lithium  
30 deuterioxide instead of potassium carbonate were used in the electrolyte, then the list of possible evolved gases 130 should include helium-4.

Thus the scope of the invention should be determined  
35 by the appended claims and their legal equivalents, rather than by the examples given.

## CLAIMS

We claim:

1. In the field of electrochemically induced excess enthalpy generation apparati of the type disclosed by Fleischmann and Pons, the improved apparatus comprising the use of an electrolytic cell containing an electrolyte characterized by an isotopic aqueous solution of a soluble compound of any isotope selected from the group comprised of thallium plus any of the alkali-type elements namely, hydrogen, deuterium, tritium, lithium, sodium, potassium, rubidium, cesium, and francium, in contact with a metallic cathode which catalyzes nuclear fusion reactions between a first reactant, namely isotopic hydrogen, and a second reactant, namely an isotope selected from said group, which reactions produce a nuclear daughter product whose mass is less than the combined masses of said reactants, so that the mass defect is converted principally into thermal energy of the contents of said cell according to the predictions of special relativity, said thermal energy becoming available for useful purposes such as heating and power generation.

2. The apparatus of Claim 1 wherein said soluble compound is selected from the group comprised of the hydroxides, the carbonates, the sulfates, the phosphates, and the nitrates.

3. The apparatus of Claim 1 wherein said metallic cathode is composed of nickel, iron, cobalt, palladium, titanium, zirconium, ruthenium, rhodium, osmium, iridium, hafnium, vanadium, uranium, platinum or an alloy thereof such as Raney nickel.



4. The apparatus of Claim 1 improved as to the catalytic reactivity of said cathode by increased porosity of said cathode in order to increase its ratio of surface area to volume and its local radii of curvature.

5. The apparatus of Claim 4 wherein said cathode is characterized by a sinter-bonded mixture of fibers and powder of a selected metal.

6. The apparatus of Claim 5 wherein said selected metal is nickel.

7. The apparatus of claim 1 wherein said cathode is improved as to catalytic reactivity by increased surface to volume ratio in comparison to the known compact, solid, rodlike cathodes by being geometrically non-compact, porous, and selected from the group comprised of annular, cylindrical, and plate-like cathodes.

8. The apparatus of Claim 1 wherein the atomic-lattice microstructure of said cathode is optimized by an external electrical automatic control system based upon the magnetostrictive and electrostrictive properties of the metal comprising said cathode.

9. The apparatus of Claim 1 wherein said isotopic aqueous solvent is ordinary water.

10. The apparatus of Claim 1 wherein said first isotopic reactant is principally hydrogen.

11. The apparatus of Claim 1 wherein said first isotopic reactant is principally heavy hydrogen, namely its isotope deuterium.

12. The apparatus of Claim 1 wherein said first isotopic reactant is principally super-heavy hydrogen, namely its isotope tritium.

5 13. The apparatus of Claim 1 wherein said second isotopic reactant is principally an isotope of hydrogen and said daughter product is principally an isotope of helium.

10 14. The apparatus of Claim 1 wherein said second isotopic reactant is principally an isotope of lithium and said daughter product is principally an isotope of helium.

15 15. The apparatus of Claim 1 wherein said second isotopic reactant is principally an isotope of sodium and said daughter product is principally an isotope of magnesium.

16. The apparatus of Claim 1 wherein said second isotopic reactant is principally an isotope of potassium and said daughter product is principally an isotope of calcium.

20 17. The apparatus of Claim 1 wherein said second isotopic reactant is principally an isotope of rubidium and said daughter product is principally an isotope of strontium.

25 18. The apparatus of Claim 1 wherein said second isotopic reactant is principally an isotope of cesium and said daughter product is principally an isotope of barium.

19. The apparatus of Claim 1 wherein said second isotopic reactant is principally an isotope of thallium and said daughter product is principally an isotope of lead.

5 20. In the field of electrochemically induced excess enthalpy generation methods of the type disclosed by Fleischmann and Pons, the improved method comprising the steps of:

10 preparing of an electrolytic cell;  
selecting for use in said cell an electrolyte comprised of an isotopic aqueous solution of a soluble compound of any isotope selected from the group comprised of thallium plus any of the  
15 alkali-type elements, namely hydrogen, deuterium, tritium, lithium, sodium, potassium, rubidium, cesium, and francium;

20 providing for contact between said electrolyte and a metallic cathode which catalyzes nuclear fusion reactions between a first reactant, namely isotopic hydrogen, and a second reactant, namely an isotope selected from said group; thereby

producing a nuclear daughter product whose mass is less than the combined masses of said reactants; thereby

25 converting the mass defect principally into thermal energy of the contents of said cell according to the predictions of special relativity; thereby

30 enabling availability of said thermal energy for useful purposes such as heating and power generation.

21. The method of Claim 20 wherein said soluble compound is selected from the group comprised of the hydroxides, the carbonates, the sulfates, the phosphates, and the nitrates.

5 22. The method of Claim 20 wherein said metallic cathode is composed of nickel, iron, cobalt, palladium, titanium, zirconium, ruthenium, rhodium, osmium, iridium, hafnium, vanadium, uranium, platinum or an alloy thereof such as Raney nickel.

10 23. The method of Claim 20 improved as to the catalytic reactivity of said cathode by increased porosity of said cathode in order to increase its ratio of surface area to volume and its local radii of curvature.

15 24. The method of Claim 22 wherein said cathode consists of a sinter-bonded mixture of fibers and powder of a selected metal.

25. The method of Claim 22 wherein said selected metal is nickel.

20 26. The method of Claim 20 wherein said cathode is improved as to catalytic reactivity by increased surface to volume ratio in comparison to the known compact, solid, rodlike cathodes by being geometrically  
25 non-compact, porous, and selected from the group comprised of annular, cylindrical, and plate-like cathodes.

27. The method of Claim 20 wherein the atomic-lattice microstructure of said cathode is optimized by an external electrical automatic control system based upon the magnetostrictive and electrostrictive properties of the metal comprising said cathode.

28. The method of Claim 20 wherein said isotopic aqueous solvent is ordinary water.

29. The method of Claim 20 wherein said first isotopic reactant is principally hydrogen.

30. The method of Claim 20 wherein said first isotopic reactant is principally heavy hydrogen, namely its isotope deuterium.

31. The method of Claim 20 wherein said first isotopic reactant is principally super-heavy hydrogen, namely its isotope tritium.

32. The method of Claim 20 wherein said second isotopic reactant is principally an isotope of hydrogen and said daughter product is principally an isotope of helium.

33. The method of Claim 20 wherein said second isotopic reactant is principally an isotope of lithium and said daughter product is principally an isotope of helium.

34. The method of Claim 20 wherein said second isotopic reactant is principally an isotope of sodium and said daughter product is principally an isotope of magnesium.

35. The method of Claim 20 wherein said second isotopic reactant is principally an isotope of potassium and said daughter product is principally an isotope of calcium.

5        36. The method of Claim 20 wherein said second isotopic reactant is principally an isotope of rubidium and said daughter product is principally an isotope of strontium.

10       37. The method of Claim 20 wherein said second isotopic reactant is principally an isotope of cesium and said daughter product is principally an isotope of barium.

15       38. The method of Claim 20 wherein said second isotopic reactant is principally an isotope of thallium and said daughter product is principally an isotope of lead.

20       39. The apparatus of Claim 1 wherein said group is expanded to include any isotope of any element whose nucleus has the property that when it combines with an isotopic hydrogen nucleus the resulting nucleus is predicted by conventionally accepted nuclear physics calculations to have a mass defect.

25       40. The method of Claim 20 wherein said group is expanded to include any isotope of any element whose nucleus has the property than when it combines with an isotopic hydrogen nucleus the resulting nucleus is predicted by conventionally accepted nuclear physics calculations to have a mass defect.

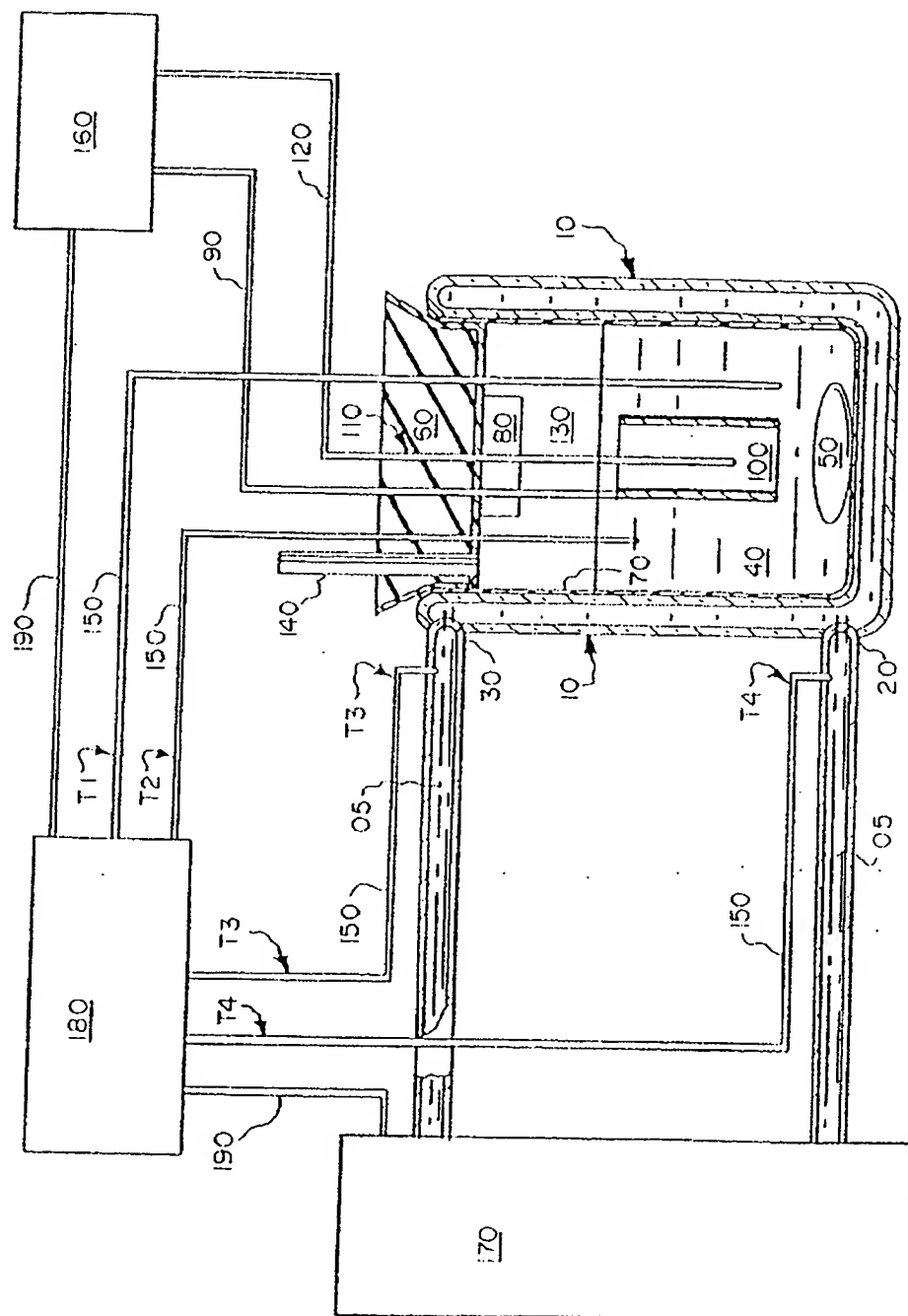


FIG. 1

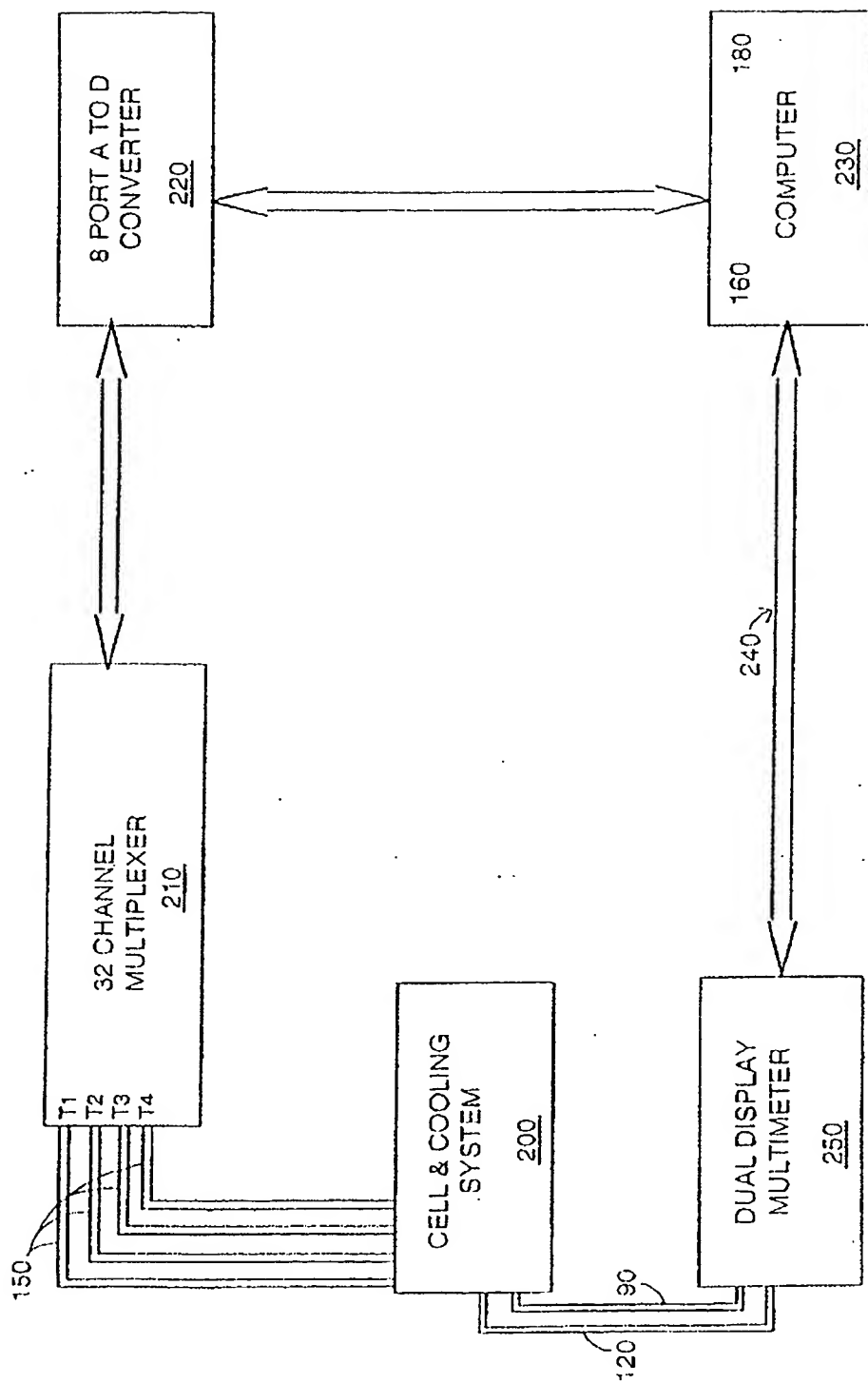


FIG. 2



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US93/01615

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : G21B 1/00

US CL : 376/100

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 376/146;204/129,239,262,274,284,290R,204/290F,292,293;205/60

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO/A, 90/10935 (Pons et al.) 20 September 1990, (See pages 19,20,29,30,34,83,84,87).	1-4, 6-12, 14-16, 18, 20-23, 25-35, 37, 39, 40
X	Fusion Technology, vol. 17, May 1990, Matsumoto, pages 490-492.	1, 3, 8-11, 13, 15, 20, 22, 27-30, 32, 34, 39, 40

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

Special categories of cited documents:	
*A* document defining the general state of the art which is not considered to be part of particular relevance	*T* later documents published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*E* earlier document published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*I* documents which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*O* document referring to an oral disclosure, i.e., exhibition or other means	*Z* document member of the same patent family
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

11 JUNE 1993

Date of mailing of the international search report

13 JUL 1993

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Form PCT/ISA/210 (second sheet)(July 1992)\*

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US93/01615

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO,A, 92/02020 (Liebert et al.) 06 February 1992, see pages 7,9.	1,3,4,6-8,11,13-18,20,22,23,25-27,29,30,32-37,39,40
Y	US,A, 3,527,614 (Elema et al.) 08 September 1970, see the abstract.	3-7,22-26
Y	US,A, 4,628,593 (Fritts et al.) 16 December 1986, see the abstract and col. 1.	3-7,22-26
X	Fusion Technology, vol.17, July 1990, Storms et al, pages 680-695 (note particularly the bottom of pages 681 and 683).	1-3,8,10-22,27,29-40
X	WO,A, 90/13126 (Mills) 01 November 1990, see particular pages 35,37,56,79,86.	1-3,8-22,27-40
Y	WO,A, 90/16070 (Bumlik et al) 27 December 1990, see pages 2-6.	1-3,10-14,19-22,29-33,38-40
X	US,A, 4,986,887 (Gupta et al.) 22 January 1991, see the abstract and cols. 1-6.	1-4,7-14,20-23,26-33,39,40
<del>X</del> Y	Nature, vol. 342, November 1989, Williams et al, pages 375-384 (also cited as casting doubt on obtaining nuclear reactions electrochemically).	1-4,7-15,20-23,26- <u>34,39,40</u> 1-40
<del>X</del> L	Nature, vol. 340, 17 August 1989, Lewis et al, pages 525-530 (also cited as casting doubt on obtaining nuclear reactions electrochemically).	1-3,8-14,20-22,27-33, <u>39,40</u> 1-40
L	C & EN, 14 June 1993, pages 38-40, Dagani (cited as casting doubt on obtaining nuclear reactions electrochemically).	1-40

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US93/01615

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:  
(Telephone Practice)  
Please See Extra Sheet.

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.  
☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US93/01615

## BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

There is lack of unity under PCT Rule 13 because the claims are directed to the independent and distinct species set forth below in Groups I-VII. Independent claims 1 and 20 (due to their "Markush" terminology) include each of the species set forth below in Groups I-VII. PCT Rule 13.2 indicates there is unity of invention only if there is a "special technical feature", common to all the inventions which defines the contribution which each of the inventions, makes over the prior art. In the present case, there is no common "special technical feature" because independent claims 1 and 20 are not patentable over the prior art (they have been found to lack novelty over several references including Pons et al.) Indeed, as set forth in PCT/ISA/210, all claims have been found to either lack novelty or lack an inventive step, thus providing further evidence that there is no common special technical feature which defines the contribution which each of the inventions makes over the prior art.

Group I. The embodiment wherein the second reactant is an isotope of hydrogen (claims 1-13,20-32,39,40).

Group II. The second reactant is an isotope of lithium (claims 1-12,14,20-31,33,39,40).

Group III. The second reactant is an isotope of sodium (claims 1-12,15,20-31,34,39,40).

Group IV. The second reactant is an isotope of potassium (claims 1-12,16,20-31,35,39,40).

Group V. The second reactant is an isotope of rubidium (claims 1-12,17,20-31,36,39,40).

Group VI. The second reactant is an isotope of cesium (claims 1-12,18,20-31,37,39,40).

Group VII. The second reactant is an isotope of thallium (claims 1-12,19-31,38-40).